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COMPARISON OF MACHINED SURFACE QUALITY OBTAINED BY HARD TURNING AND CONVENTIONAL TURNING

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ABSTRACT

The authors of this paper aim to present results of investigation on machined surface quality achieved by turning of steels with different hardness value. Tests have been made on two steel rods hardness of 52 HRc and 240 HB. Harder material has been cut by using CBN inserts while softer work was machined with Cermet insert. Factorial plan 2^3 was used for conducting experimental investigation, which main goal has been to define cutting conditions that produce the best results of machined surface.

Keywords: turning, hard steel, factorial design

1. INTRODUCTION

Surface quality play very significant role in most of machine elements and various products. It may be demanded as a precondition for correct functioning of designed part especially when the part is included in more complex structure or for example when the friction affects the function of part. In machining operations, obtaining and produce good surface quality became main task in many applications. Finishing operations, like grinding, honing, super-finish etc, have been set so to achieve best possible quality. But, those operations are very expensive one, time consuming, and highly cost connected operations. Today, when environmental protection takes more and more important position in all aspects of human production and activity, finishing operations, like grinding, which is characterized by intensive use of cooling lubricants, need to be replaced by other environmentally friendlier operations. One of such operations is of course hard turning that can be performed without any cooling lubricants. Yet, some analysis has been done [1] on investigation the influence of small quantity of lubricants on surface quality in hard turning. This research showed that lubricants can improve results of hard turning, lowering cutting forces and improving surface quality, but the level of it have to be limited on for example in this case 50 to 500 ml/hour. On the other side, it has been known [2] that for example European automotive industry expense more than 20% of the total manufacturing cost on cooling lubricants. At the same time on cutting tools cost goes only 7,5 % of the same. So it is obvious that any improvements aiming to reduce cost of lubricants are more than desirable. This also explain fact that main applications of hard turning includes gears and pinions (35%), roller bearings (25%), shafts (20%) and housings (5%) more specially dedicated to automotive industry [3]. This enforces investigation on dry or near dry cutting techniques, and hard cutting is definitely one among them. According to many researchers that have been investigated hard cutting, continuous or interrupted, main factors that influence on surface quality are the corner radius of the cutting edge and the feed rate. [4]. So, generally speaking the greater the feed, the greater the value of Ra. This paper also considers influence of cutting conditions on surface machined quality.

2. EXPERIMENTAL SETUP

The experiment has been conducted on universal lathes ADA Potisje. It should be notice that this machine is not designed for hard turning. Yet, these machines are still in use very frequently in area of Western Balkan Countries and broader. They are constructed for wide range of operations to perform, even hard turning can be done, too, but expected results can not be the same as in case of modern, specially design for hard turning, lathes. Following cutting conditions has been used in the experiment:

Table 1. –The values of factor levels

Factors		*Lower level (-1)*	*Upper level (+1)*	*Centre point*	*Lower level (-1)*	*Upper level (+1)*	*Centre point*
Cutting speed, mpmin	X_1	*140*	*250*	*195*	*100*	*250*	*175*
Feed, mprev	X_2	*0,04*	*0,124*	*0,082*	*0,05*	*0,20*	*0,125*
Depth of cut, mm	X_3	*0,2*	*0,6*	*0,4*	*1*	*2*	*1,5*
		Cutting tool: CBN, Steel 52 HRc			*Cutting tool: CERMET, HB 240*		

Full factorial design 2^3 with 2 replicates in center point and 3 replicates on each corner point. Experimental runs have been randomized and looks like the one presented in table2.

Table 2. – Plan of experiment with measuring results for parameter Ra in case of steel 52 HRc

Run.	*Plan-matrix*				*Ra (μm)*			*Ra average*	
		Cutting speed	*Feed*	*Depth of cut*	*Measuring*				
	x_0	x_1	x_2	x_3	*I*	*II*	*III*	*y*	*lny*
1	1	-1	1	1	1,383	1,19	1,222	1,265	0.2351
2	1	-1	-1	-1	0,408	0,43	0,427	0,4217	-0.8635
3	1	1	-1	-1	0,448	0,451	0,441	0,4467	-0.8059
4	1	-1	-1	1	0,528	0,476	0,527	0,5103	-0.6727
5	1	-1	1	-1	1,074	1,003	1,031	1,036	0.0354
6	1	0	0	0	0,61	0,609	0,527	0,582	-0.5413
7	1	1	1	1	0,923	0,944	1,011	0,9593	-0.0415
8	1	0	0	0	0,603	0,563	0,539	0,5683	-0.5651
9	1	1	-1	1	0,396	0,403	0,368	0,389	-0.9442
10	1	1	1	-1	0,771	0,781	0,809	0,787	-0.2395

It can be seen that different cutting conditions have been applied for different materials as well as for different cutting tools inserts. In case of softer material Cermets inserts, grade IN 22, designation CNGA 120408T have been used while for machining of hard steel CBN inserts, grade IB50, designation CNMA 120408T was employed. Both types of inserts are product of Iscar Ltd. company. Cutting conditions has been chosen according to producer recommendations. Beside average roughness Ra, other parameters, Rz and Rmax, have been also measured. Measuring was performed on Perthometer M1 device product of Karl Mahr company, Goetingen. Results have been handled by MarSurf XR20 V1-21.1 software.

3. ANALYSIS OF RESULTS

In table 2. are presented results obtained for turning of hardened steel, 52 HRc, with CBN inserts, and cutting conditions as listed in table 1. Similar tables are made for all cases, both material, both cutting tools and all parameters. Analysis of results has been done by Data Analysis Tool Pack from Microsoft Excel software package. It has been assumed that exponential function is possible description of relations between parameters and cutting conditions:

$$Ra = C \cdot v^{x} \cdot f^{y} \cdot d^{z} \qquad (3.1)$$

where is: **C**, *constant*; **v**, *cutting speed*; **f**, *feed rate*; **d**, *depth of cut;* **x, y, z**, *exponents*

SUMMARY OUTPUT							
Regression Statistics		*ANOVA- Analysis of Variance*					
			df	*SS*	*MS*	*F*	*Signif. F*
Multiple R	*0.9706621*						
R Square	*0.9421850*						
Adjusted R Square	*0.9132776*	*Regression*	*3*	*1.4399228*	*0.4799742*	*32.593116*	*0.0004134*
Standard Error	*0.1213517*	*Residual*	*6*	*0.0883574*	*0.0147262*		
Observations	*10*	*Total*	*9*	*1.5282803*			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	*-0.44032*	*0.03837479*	*-11.474199*	*2.63109E-05*	*-0.534219*	*-0.3464203*
x_1	*-0.095675*	*0.04290432*	*-2.229961*	*0.06726945*	*-0.200658*	*0.0093081*
x_2	*0.409475*	*0.04290432*	*9.543910*	*7.55374E-05*	*0.304491*	*0.5144581*
x_3	*0.056275*	*0.04290432*	*1.311639*	*0.237592802*	*-0.048708*	*0.1612581*

Linear regression model obtained in this case is as following:

$$\hat{y} = -0.44032 - 0.09567 \cdot x_1 + 0.40947 \cdot x_2 + 0.05627 \cdot x_3 \quad (3.2)$$

Transforming this model into natural coordinates gives:

$$Ra = 27.547 \cdot v^{-0.33} \cdot f^{0.724} \cdot d^{0.103} \quad (3.3)$$

In table 3. are shown all models for both steels.

Table 3. – Obtained results for all experimental settings

Hardness – 52 HRc, CBN	Hardness, 240 HB, Cermet
$Ra = 27.547 \cdot v^{-0.33} \cdot f^{0.724} \cdot d^{0.103}$	$Ra = 16.3 \cdot v^{-0.081} \cdot f^{0.809} \cdot d^{-0.048}$
$Rz = 41.059 \cdot v^{-0.191} \cdot f^{0.481} \cdot d^{0.16}$	$Rz = 50.3 \cdot v^{-0.075} \cdot f^{0.564} \cdot d^{-0.074}$
$R\max = 35.375 \cdot v^{-0.171} \cdot f^{0.41} \cdot d^{0.178}$	$R\max = 70.704 \cdot v^{-0.1187} \cdot f^{0.534} \cdot d^{-0.105}$
$Pn = 24.986 \cdot v^{0.066} \cdot f^{-0.264} \cdot d^{-0..018}$	$Pn = 17.48 \cdot v^{-0.0135} \cdot f^{-0.542} \cdot d^{-0..0055}$

Figure 1. shows graphical interpretation of generated results for only one parameter – Ra, in case of both machined materials.

4. CONCLUSION

Presented results confirmed feed rate as a factor with strongest influence on surface quality. Character of all factors influence is more or less the same in both cases. So, increasing in feed rate results in deterioration of surface quality. At the same time increasing in cutting speed improve surface quality. Depth of cut change may produce both, increasing as well as decreasing of surface quality; depend of cutting conditions and hardness of material to cut.

Anyway, results shows that even on the selected machine tool is possible to perform hard cutting, achieving surface quality in N5-N6 class that is appropriate for grinding operations. In case of machining softer material 240 HB, additional finishing operations are necessary for achieving surface quality that correspond to grinding operation.

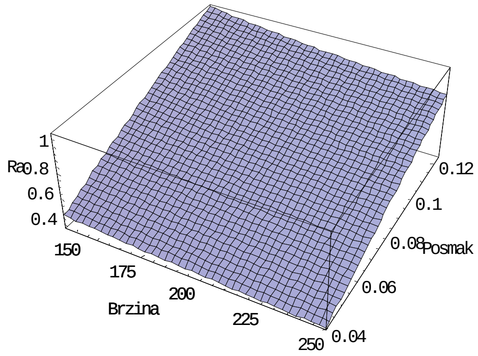
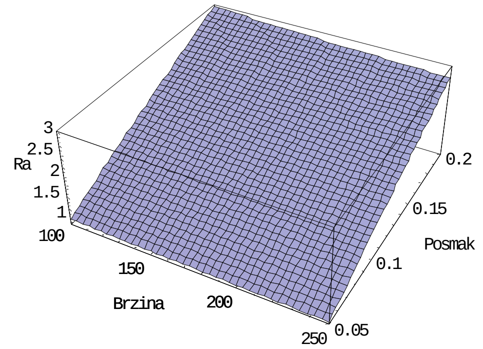
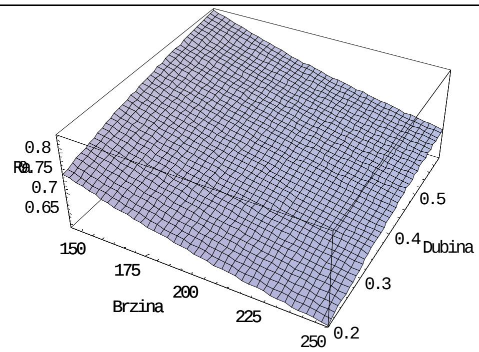
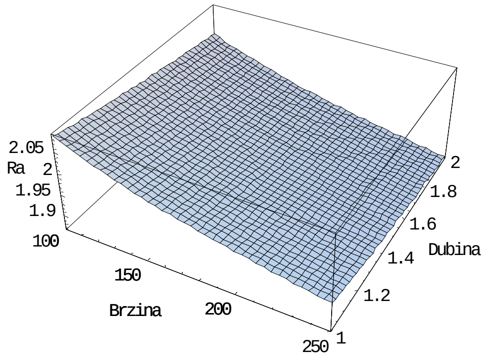
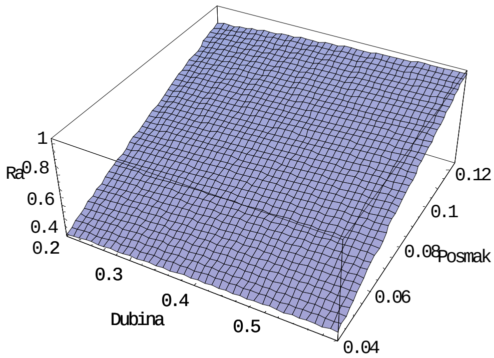
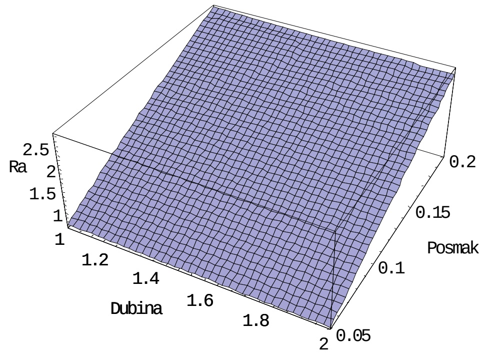
52 HRc – CBN - Ra	240 HB – CERMET - Ra
 *Ra=f(v,f), d=const.*	 *Ra=f(v,f), d=const.*
 *Ra=f(v,d), f=const*	 *Ra=f(v,d), f=const.*
 *Ra=f(d,f), v=const*	 *Ra=f(d,f), v=const.*

Figure 1. –Cutting conditions influence on average roughness Ra

5. REFERENCES

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